exceed 75,000 cfs. We believe the Yolo Bypass and similar areas provide important spawning, rearing, and foraging habitat, leading to successful recruitment. In support of that hypothesis, Resident Fishes PWT surveys of the basin demonstrated that:

- Adult splittail move into the bypass during spawning periods, and
- Catch of larval splittail at the Yolo Bypass outfall was significantly higher than at stations in the Sacramento, American, and Feather rivers. In fact, larval density was among the highest observed anywhere in the estuary.

We also reviewed other factors that may influence splittail abundance, including salinity and water project entrainment. Analysis of Suisun Marsh field data confirmed the findings of UC-Davis laboratory studies (Young and Cech 1995) that splittail are fairly halotolerant. They are abundant across a broad range of salinity, as opposed to delta smelt, which show a distinct peak in abundance around 0.2-1.0 ppt. Salvage data since 1979 suggest the SWP has not had an important effect on splittail population level. Splittail abundance is positively correlated with salvage, contrary to the hypothesis that entrainment losses should decrease abundance. In other words, splittail entrainment is primarily determined by abundance in the system, rather than vice versa. Entrainment is, therefore, highest in wet years, when the splittail population is best able to accept losses. This contrasts to delta smelt and longfin smelt, which show higher salvage in drier years, when their populations are typically lowest.

Conclusions

Despite reduced abundance of young splittail during extended drought, the population still appears resilient. The strong 1995 year class is an excellent example — record indices were produced after drought in 7 of 8 preceding years, a period that could reasonably have been expected to deplete the stock. Attributes that help the population respond quickly to improved environmental conditions include a long life span and high fecundity. Splittail distribution does not appear to have changed much over the past two decades, although it varies substantially between years. Year class strength appears to be controlled primarily by inundation of floodplain areas, such as Yolo Bypass, which provide spawning, rearing, and foraging habitat. Water project entrainment does not appear to have an important effect on population level, but the variability in distribution of young splittail suggests we should continue to monitor their distribution and salvage. A shift in distribution toward the export facilities coupled with reduced abundance in dry years could affect population levels, but this has not been detected.

Finally, several important issues should be pursued. Splittail remains under consideration as a threatened species — better data are needed on its basic biology to help guide policy-makers and regulators. In particular, we need to determine why abundance of splittail young and adults has remained relatively low in the Suisun Marsh/Chipps Island region since the early 1980s. One possibility is that high abundance in the late 1970s and early 1980s was the result of a localized spawning event. Additional studies are needed to answer this question. Another key issue is whether splittail abundance can be improved in dry years by constructing more habitat. At present, the Yolo Bypass floods in only one-third of water years, and it appears that at least 30 days of flooding during the splittail spawning season are needed for development of a strong year class. Proposals to increase the amount of shallow water and flood-plain habitat might have major benefits to abundance in dry to moderately wet years. However, we need better information on the optimum habitat features for spawning and rearing to help design restoration efforts.

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Unusual Weather

Maurice Roos, Chief Hydrologist, and Bill Mork, State Meteorologist (DWR)

December and January were the wettest 2-month period in our record, with some record-breaking floods, but February through May were the driest 4-month sequence on record at most locations from Interstate 80 southward. June may have marked a turn-around, in that northern Sierra precipitation was more twice the average. June precipitation is only 2% of the annual total, so the high percentage doesn't mean much for runoff. Figure 1 shows how this water year's precipitation in the northern Sierra compares with average and with 1995 and 1996.

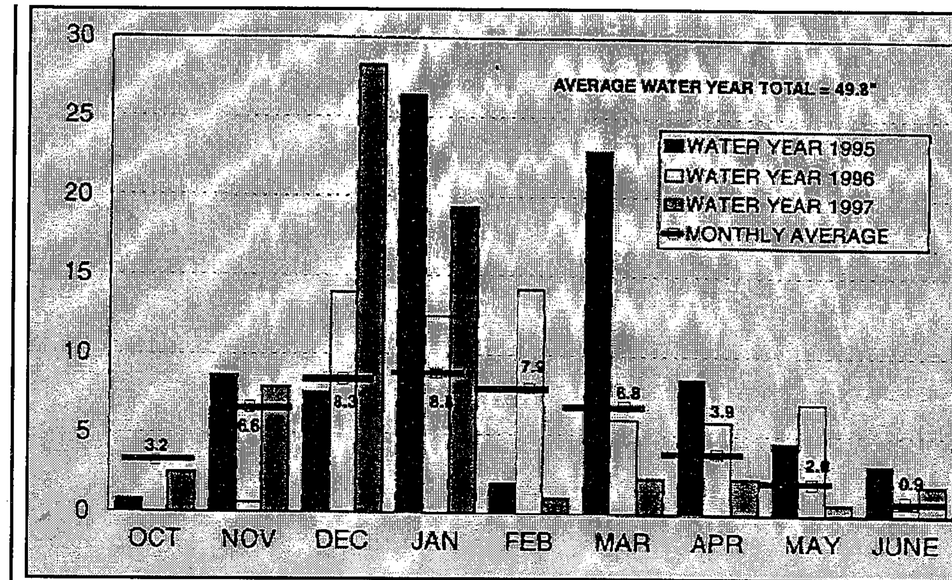

Figure 1
NORTHERN SIERRA PRECIPITATION, 8-STATION AVERAGE
In Inches

This year has also been warmer than average. Sacramento had its warmest spring and third warmest winter on record. Monthly average temperatures at Sacramento are:

	Water Year 1997	1961-1990 Average
October 1996	66.1	65.8
November 1996	57.2	54.9
December 1996	52.4 (2nd warmest)	47.1
January 1997	50.0	47.1
February 1997	54.9	52.9
March 1997	61.2 (2nd warmest)	56.1
April 1997	64.7 (5th warmest)	60.8
May 1997	74.5 (warmest)	67.2
June 1997	74.7	73.0

The lack of spring precipitation caused an unusual snowpack pattern. In an average year, the February 1 snowpack is 65% of the April 1 amount. Accumulation continues through February and March for the peak seasonal amount on about April 1. This year, the February 1 statewide snowpack was estimated to be about 100% of the April 1 average. March 1 snowpack measurements showed essentially no change, still 100%, although there were large regional differences. Warmer than average temperatures in March caused early melting of the snowpack, especially at lower elevations, and the estimated pack was 75% of average on April 1. By May 1, the statewide snowpack had dropped to 45% of the April 1 average, with only about 25% in the Sacramento River region. One could say snowmelt was about a month early in 1997.

There was a good snowpack at Christmas, but the warm flood-producing storms at year end melted the lower elevation snowpack. Since the northern Sierra snow fields are at lower elevation than in the southern Sierra, loss in snowpack and subsequent spring runoff there were proportionately greater in the north. Estimated snowmelt runoff this year is 70% of average in the Sacramento River region, 100% in the San Joaquin River region, and 120% in the Tulare Lake region. The east side of the Sierra had a similar pattern, with amounts south of Lake Tahoe well above average. Table 1 shows some percentage comparisons.

Table 1
ESTIMATED MONTHLY RUNOFF, WATER YEAR 1997
Percent of Average *

Month	Northern Sierra Precipitation	Estimated Unimpaired Runoff* Statewide	Sacramento	San Joaquin
October	75	80	90	60
November	120	100	100	200
December	340	300	310	380
January	220	390	370	840
February	15	90	90	125
March	35	80	70	125
April	60	85	70	110
May	35	85	60	115
June	230	80*	60*	80*

*Sacramento is the sum of Sacramento (above Bend Bridge near Red Bluff), Feather, Yuba, and American rivers. San Joaquin is the sum of Stanislaus, Tuolumne, Merced, and San Joaquin (at Friant) rivers.
**Estimated

As an observation, the runoff patterns this year are more nearly the kind to be expected in a globally warmer world if climate change did occur. Such a change would produce more winter runoff, possibly more winter floods, and a reduction in spring snowmelt runoff, particularly in the northern Sierra. The climatologists are still debating whether Earth's climate is actually warming. The signals are mixed. One has to weigh our warm weather this year with the very cold and snowy winter in the upper Midwest. The recent warm months in much of California are probably associated with a large patch of warmer-than-usual surface water — up to 3°C above average in May — off the California coast. We don't believe this warm water offshore is linked to El Niño in the equatorial eastern Pacific.

Unusually early warming was noted in May in the tropical eastern Pacific Ocean. Assuming the usual progression of ocean warming (El Niño events usually peak in late fall or winter) the National Weather Service has predicted a large El Niño event this fall and winter, with worldwide impacts on weather. Expected consequences are dry conditions in northeastern Australia, Indonesia, northern India, northeastern Brazil, and the Pacific Northwest and wetter than average conditions in California, the American Southwest and Gulf States, Chile, and Peru. It remains to be seen whether the Pacific warming will continue or whether something else will happen. For large El Niño events, the signal is stronger in Southern California, less in Northern California and the northern Sierra. Some El Niño years have been dry in Northern California. If the warmth off the California coast persists, it could lead to more tropical storm penetration into California during August and September.

Predicting Evolution of Shallow-Water Habitat Ecological Function from Restoration of Managed Delta Islands

Zachary Hymanson, DWR, and Charles Simenstad, University of Washington

Interagency Program staff will be collaborating on an interdisciplinary, consortium-based research project to investigate the timing and type of ecological benefits gained from shallow-water habitat restoration in the delta. The project, approved as a 1996 Category III project, will be led by Charles "Si" Simenstad from the University of Washington, School of Fisheries, Wetland Ecosystem Team.

The project aims to determine the potential for wetland restoration to provide aquatic resource functions and habitat thought important to improving the ecological health of the delta. Results will provide critical information necessary to predict whether breached-dike restoration strategies contemplated in the CALFED planning process will provide the expected ecosystem benefits to aquatic resources dependent on the delta. Further, the study is expected to provide information useful to restoration projects in progress on Prospect, Sherman, and Decker islands.

The study will assess the long-term prognosis of restoring function to former wetlands now existing as managed islands through a *space-for-time substitution* approach. Rather than depending on long-term ecological databases on tidal wetland development, which are essentially unavailable for the region, a space-for-time substitution approach will compare the habitat and function of historically breached islands of various ages to several natural reference sites. These comparisons will be used to predict the patterns and rates of habitat and function development of shallow-water restoration projects.

Objectives of the project include:

- Assess hydrological, geomorphological, biogeochemical, and ecological indicators of flooded agricultural islands of various ages;
- Complete comparisons between the previously flooded islands and adjacent reference sites using indices of habitat quality for fish, invertebrates, and other flora and fauna; and
- Using various indicators, compare the state of wetland functions at the flooded islands to the functions of natural marsh sites.

Ultimately, the information will be used to develop conceptual models describing the shape and rate of development of trajectories for fish and wildlife habitat functions in flooded delta islands.

DWR will conduct the fish study element of the project through the Interagency Program. DWR staff in the Environmental Services Office will lead the planning and implementation of the fish study element, completing the data analyses and reporting the results. Coordinating the fish study element with the IEP project work teams will also be the responsibility of DWR.

The University of Washington and Metropolitan Water District are nearing completion of the required project contract. Subcontracts will then be developed between the university and the other partners in the study, including DWR, Philip Williams and Associates, and LUMCON. In addition, DWR staff are securing project permits from USFWS, NMFS, and DFG. The partners will begin final study design late this summer and begin the study this fall. Contact Zach Hymanson (916/227-7543) for more information.

Effects of Reduced Wastewater Phosphate Concentrations in South San Francisco Bay

Steve Hager and Larry Schemel, USGS

Wastewater from municipal treatment plants is an important source of freshwater and chemical species to the lagoonal southern reach of the San Francisco Bay estuary (South Bay; Figure 1). Observations over almost four decades have shown that the chemical composition of the wastewater strongly influences longitudinal concentration gradients of dissolved nutrients, particularly in the shallow, landward reach south of the San Mateo Bridge (cf. Harris *et al* 1961; Conomos *et al* 1979; Schemel and Hager 1996). It follows that changes in wastewater treatment that cause changes in the chemical composition of wastewater could affect distributions of dissolved nutrients in South Bay. We previously showed an example of this with respect to a 1979 upgrade to tertiary treatment by the San Jose/Santa Clara Water Pollution Control Plant, which resulted in decreased concentrations of ammonium and increased concentrations of nitrate in the landward reach (Hager and Schemel 1996). Here, we show the effects of a decrease in phosphate loading by two wastewater treatment plants that discharge into the landward reach of South Bay.

In late 1992 and early 1993, phosphate loading south of Dumbarton Bridge was rapidly reduced by more than 50% from its previous 3-year mean value (Figure 2). This reduction was due to significant reductions in phosphate concentrations in effluent from two wastewater treatment plants and apparently did not result from decisions to reduce phosphate loadings. For example, in May 1993, the plants began using alternating anoxic and oxic zones in some activated sludge ponds to control the growth of filamentous algae without using more chlorine. This mode of operation also increases biological phosphorus removal (Alex Ekster, SJ/SC WPCP, personal communication, March 21, 1997). As a result, phosphate concentrations in the effluent were reduced to about 40% of previous values. Causes of a smaller reduction in phosphate concentrations in the effluent of the Palo Alto Municipal Wastewater Treatment Plant over a period of months beginning in late 1992 have not yet been resolved.

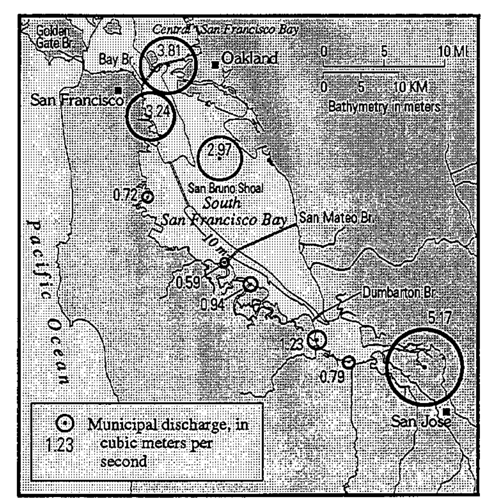

Figure 1
LOCATION MAP FOR SOUTH BAY
Diameters of circles are proportional to volumes of wastewater.
Data from Hager and Schemel 1996, Table 3.

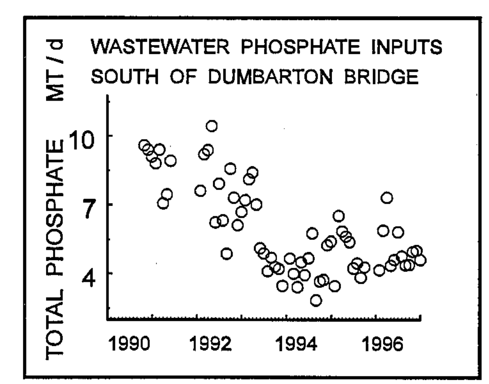

Figure 2
RECENT HISTORY OF MONTHLY LOADINGS OF TOTAL PHOSPHATE SOUTH OF DUMBARTON BRIDGE
(Metric Tons per Day)
Data from monthly reports by the wastewater treatment plants to the Regional Water Quality Control Board.

For much of an average year, wastewater plants south of Dumbarton Bridge are also the only sources of freshwater to that part of the bay. Thus, transect plots of wastewater-derived substances versus salinity may have zero-salinity intercepts equal to the wastewater concentration and slopes determined by mixing this wastewater with bay water. Because the volume of wastewater discharged daily south of Dumbarton Bridge is only about 0.7% of the mean tide volume of that part of the bay, observations during our routine sampling program did not show reduced slopes and intercepts until fall 1993. Data from November 1993 showed a reduced slope extending to Coyote Hills Slough (seaward of Dumbarton Bridge, 22 km from the plant). By February 1994, the reduced slope extended to just seaward of the San Mateo Bridge (34 km from the plant). Over the next 3 years, however, concentrations of phosphate were also lowered by freshwater inflow to South Bay, by exchange with the freshened water of central San Francisco Bay, and by spring phytoplankton blooms. As a result, phosphate concentrations in the landward reach after the major change in phosphate loading (circles) were not consistently lower than those before the change (plus signs), even when referenced to salinity (Figure 3). Only when data are selected for times when freshwater inputs and phytoplankton populations were low (eg, November) do reduced slopes and intercepts stand out in a phosphate/salinity plot (Figure 4). Clearly, other sources also influence these slopes, and we are developing numerical models to quantify the influence of the small mid-bay wastewater input, the larger more northerly wastewater input, and benthic fluxes.